DIURNAL VARIATIONS FROM MUON DATA AT TAKEYAMA UNDERGROUND STATION

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ABSTRACT

An underground station, Takeyama, is introduced, and some results of the solar diurnal and semi-diurnal variations for the period between 1967 and 1984 are presented. There are clear tendency of double and single solar cycle variations in the daily variations which are in good accord with those detected by other underground and neutron monitor observations.

1. Introduction. Takeyama is the first Japanese underground station for the study of the time variations of cosmic ray intensity. The depth is 54 *mwe* which is equivalent to the median rigidity of primary cosmic rays around 200 GV. The geographic latitude and longitude are 35.22° N and 139.62° E, respectively. The continuous observation was started in September 1967. The operation was stopped in September 1981. It was restarted in June 1982. The area of detector has been increased from 9 m^2 to 16 m^2. The detector consists of 2 layers of 16 plastic scintillators, 1 m^2 each.

Since the station is situated a few tens km apart from the main laboratory, the memorized data are communicated through public telephone lines. The recording and communication modes are controled through the terminal computers set at both sites. The computer at the observation site can memorize one week data. The data are read out at the laboratory by the command. Generally the coincidence counts per hour of 256 combinations (16 × 16) are communicated. They are rearranged in the laboratory to get the counts of directional components, i.e., vertical and four azimuthal directions inclined around 30° from zenith. The observed counting rates are corrected for the pressure effect with the coefficient, -0.035 %/mb.

2. Daily variations. The yearly average solar diurnal and semi-diurnal variations are presented here. Figs.1a and 1b show the summation diagrams of the diurnal vectors of the vertical component, without and with the correction for Compton-Getting effect, respectively, for the earth's revolution around the sun. The correction values have been given by Prof. H.Ueno of Nagoya University. He has calculated them using the listed coupling coefficients (Fujimoto et al. 1984) for the variation spectrum which is flat upto essentially infinite rigidity. They are listed in Table 1.

It is clearly seen from the figures that the phases are earlier during the period from 1969 to 1980 compared with those after 1982. This tendency has already been pointed out by Swinson (1983) from his underground observations. There is a period, 1975-77, when virtually no diurnal variation is seen if Compton-Getting effect is concerned as Fig.1b. The phases of diurnal variations detected by neutron monitors are also relatively earlier in this period as seen in Fig.2. The level of cosmic ray intensity is highest and the variations are calm in the same period when the sunspot numbers are minimum.

Figs.3a and 3b show the vector diagrams of directional components for three year periods, 1978-80 and 1981-83, respectively. It is clear that the phases are later for the latter case as expected from those illustrated in Fig.1. Those results can be added on Ueno and others' "NAMS" analysis (1984) which utilizes the muon data from Nagoya, Misato, and Sakashita, and may become "NAMTS".

Fig.4 shows the summation diagram of solar semi-diurnal variation. The phases are nearly at 1.5 hour. There again some tendency of advancing the phases during the years in 1970's comparing with the periods before and after that.

Table 1. Correction values for Compton-Getting effect in percent. (after H.Ueno)

Axis	Vert.	North	East	South	West
0 hr	0.0073	0.0088	0.0227	0.0053	-0.0093
6 hr	0.0351	0.0232	0.0316	0.0422	0.0335

3. Summary. The underground observation at Takeyama is presented, with some information of the restart of observation with somewhat larger area than before. The solar diurnal and semi-diurnal variations are analyzed. The double solar cycle variation in the diurnal variation is seen. The diurnal variations in 1975-77 indicate the character of single solar cycle variation, for the period corresponds to the sunspot minimum years. Those double and single solar cycle variations are in good accord with those detected by the muon and neutron monitors.

The multi-component or multi-station analysis will give more information about the anisotropy in space. Further observation, at least until the next solar minimum with better quality, will result much complete conclusion of the analysis given above.

4. Acknowledgment. The earlier observation was performed by Prof. K.Murakami and others in the laboratory and the technical team in the Institute. The revised observation has been operated under the same members of the laboratory and of the technical workshop, specially K.Nishi and H.Kato. Prof. H.Ueno has provided us Compton-Getting values of Takeyama. We are grateful to them all.

References

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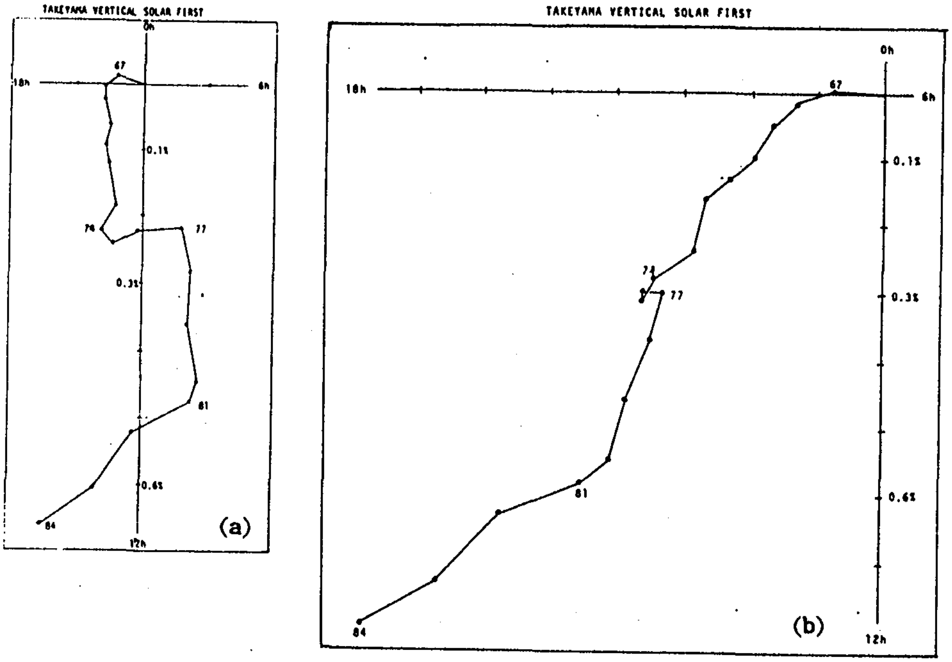

Fig.1. Summation diagrams of yearly solar diurnal variation, vertical component observed at Takeyama underground station from 1967 to 1984: (a): without, and (b): with the correction for Compton-Getting effect, respectively.

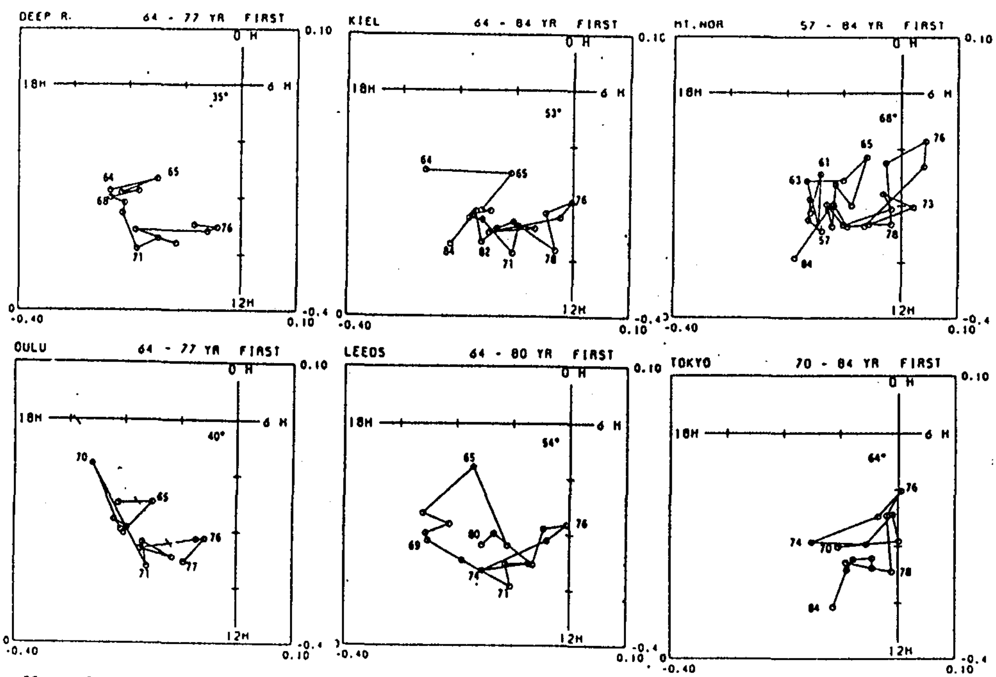

Fig.2. Yearly solar diurnal vectors of the neutron monitors. Each vector is drawn from the origin, and the lines connect the vectors to show the year to year changes. Notice the vector of 1976 which is at the upper right corner of the evolution in each graph.

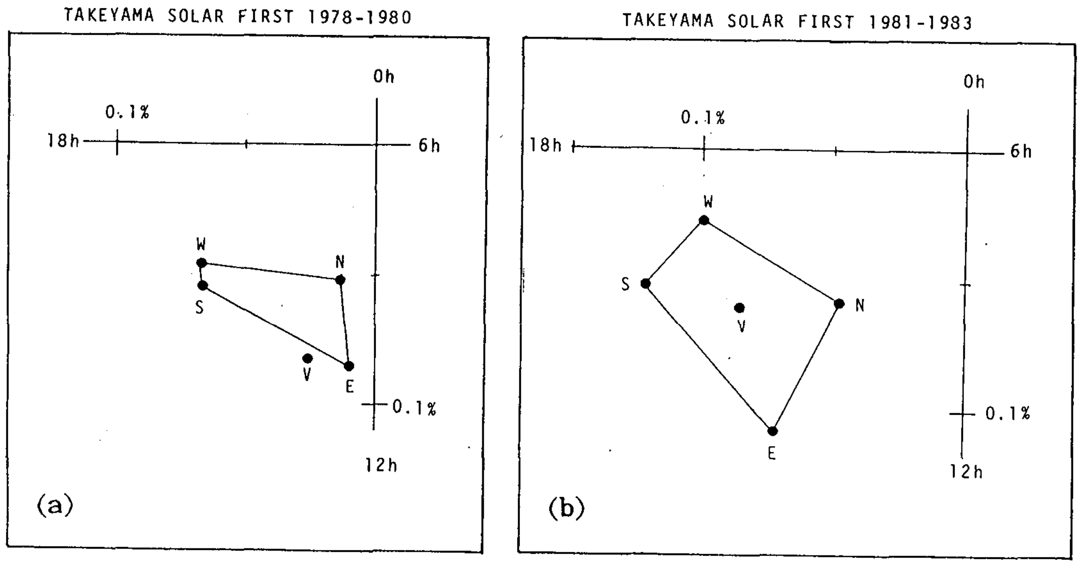

Fig.3. Solar diurnal vectors of directional components at Takeyama for the periods: (a): 1978-80, and (b): 1981-83, respectively.

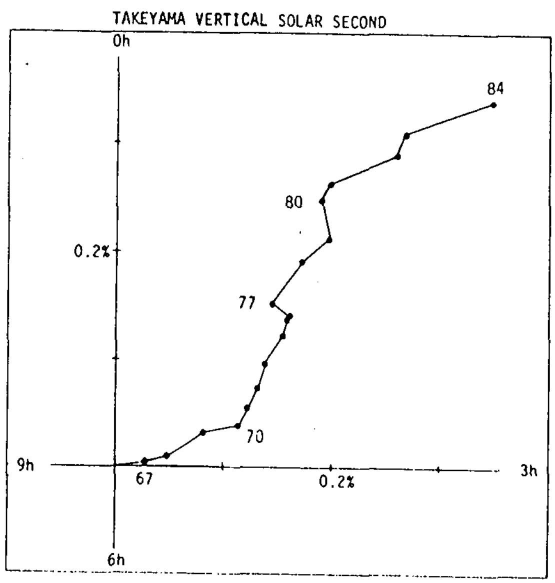

Fig.4. Summation diagrams of yearly solar semi-diurnal variation, vertical component at Takeyama for 1967-84.